

Enhanced AHS safety through the integration of vehicle control and communication

Why Was This Research Undertaken?

The main objectives of this project were to improve Automated Highway System (AHS) safety through the integration of current communication and control technology. Communication architectures are capable of reliable and efficient vehicle-vehicle/vehicle-roadside communication. With such communication, the vehicles cooperatively make the maneuver and exchange information about themselves and road conditions. We designed a control system, which integrated the communicated message into the vehicle control. Such an integrated communication and control system can greatly enhance vehicle safety, e.g. in adaptive cruise control system (ACC). The maximum coefficient of friction between the tire and the road quantifies the largest acceleration a vehicle can achieve before skidding out of control. Thus, knowledge of this parameter is a prerequisite for safely setting vehicle velocities, picking spacing policies, and designing maneuvers. Although numerous PATH maneuver design studies have assumed that the maximum friction coefficient was known, few projects have been aimed at determining this value. In this project, we proposed a method by which real-time maximum friction coefficient estimates of several vehicles can be combined together via communications to arrive at useful statistics for operating a highway. If it happens that the patch of road supporting a trailing vehicle in a platoon has less friction than the road at the front of the platoon, rear end collisions are likely during a demanding maneuver, especially if a lane change is impossible. We developed a control strategy for the emergency braking of a platoon and derived the maximum acceleration limits of the platoon when each vehicle in a platoon has different maximum friction coefficients.

What Was Done?

We comparatively assess the influence of adaptive cruise control and cooperative adaptive cruise control (CACC) systems on highway traffic behaviors. The primary goal is to study the design and implementation of vehicle-vehicle/roadside-vehicle communication, which enhances an ACC system to a CACC one. In addition, the impact of market penetration of ACC/CACC vehicles and controller aggression are also evaluated. We studied wireless communication between highway vehicles. A vehicle-vehicle Location-Based Broadcast (LBB) communication protocol was designed to meet highway safety applications' communication requirements. The analytical expressions of the protocol performance in terms of the probability of transmission failure and channel occupancy

are derived with commonly satisfied assumptions. The optimal relation between the performance and design parameters was obtained from the expressions. The sensitivity of the protocol performance was tested for various communication conditions as well as highway traffic conditions. Feasible combinations of the communication and highway traffic parameters are found for certain requirements on protocol performance. The analysis was conducted in accordance to the communication condition in the newly assigned 5.9 GHz Dedicated Short Range Communication (DSRC) spectrum.

For emergency vehicle maneuvers, we have developed a method of measuring the slip between road and tire in real time. With this measured slip data, we used the empirical relation between traction force and slip to

develop a non-linear slip-based controller. For the empirical relation, we chose to use a longitudinal tire model developed by Pacejka and Bakker. In the design of the slip-based controller, a nonlinear control approach was taken, because this matches the highly non-linear properties of the vehicle and contains robustness properties. We also built the experimental set-up for a demonstration of an emergency vehicle maneuver and calibrated the necessary sensors installed on the vehicle.

In order to integrate the benefits from the communication and friction coefficient estimation technique, a safe control strategy is considered in the situation when a platoon of vehicles needs to decelerate rapidly. It is assumed that we have the knowledge of friction coefficients between road and tire and our vehicles are equipped with proper communication methods. Then, the theoretical bounds for the reference trajectory accelerations are calculated that do not cause actuator saturation using linear vehicle and controller models.

What Can Be Concluded From The Research?

Vehicle-vehicle/Roadside-vehicle communication can bring benefits to highway traffic by increasing the average velocity, decreasing braking effort, smoothing shock wave, and shortening the queue length of merging vehicles. Higher market penetration is beneficial for both ACC and CACC systems in terms of the average vehicle velocity, braking effort, and merging queue length. With other conditions the same, an aggressive controller design increases the average velocity, therefore enhancing the efficiency. However a weaker controller saves braking effort. For the friction coefficient estimations, through various experiments, we could differentiate the wet and dry road-conditions using slip-friction coefficient curves. To obtain maximum friction coefficients by observing the slip-friction coefficient curve, more research need to be done.

What Do The Researchers Recommend?

The communication protocol design is still a challenging area in Telematics and could bring many application areas. The slip-based friction estimation can be done if one can find appropriate an tire model to explain the relationship between the slip-friction coefficient curve and the maximum friction coefficients. Measuring friction coefficients between road and tire will greatly enhance highway safety.

Implementation Strategies

For a friction-estimation, we proposed a cooperative friction estimation method using a roadside computer and the slip data from many vehicles passing highway.

For More Information About This Research

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